Pilot Study to Demonstrate Tree Height Retrievals from CAR Multiangular/ Multispectral Data

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Abstract: In remote sensing, multiangular observations are primarily governed by the view-illumination geometry, and thus, contain information on the physical structure of the upper (tree and/or shrub) canopy and (soil and/or low vegetation) background. This information can be exploited via empirical or physical modeling approaches and can lead to new algorithms for deriving accurate global aboveground biomass from space based multiangular data. In this study, we used airborne Cloud Absorption Radiometer (CAR) multiangular observations taken aboard NASA P-3B during the Eco3D field campaign (Aug – Sept. 2011) over seven well characterized terrestrial ecology study sites along the U.S. east coast to demonstrate canopy height retrieval.

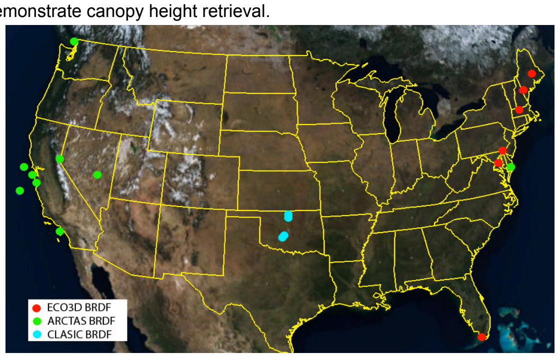


Figure 1.Locations of bidirectional reflectance-distribution function (BRDF) during different field campaigns: Eco3D-2011, ARCTAS -2008 and CLASIC -2007 in the US. This study focuses on measurements at locations shown in red for the Eco3D deployment (Aug. – Sept. 2011).

Measurements

ECO3D focuses on assessing new methods for forest biophysical parameter estimation including aboveground biomass. The campaign covers areas as far north as Quebec, Canada, and as far south as the Florida Everglades, USA (Figure 1). As part of the ECO3D field campaign, the NASA's Cloud Absorption Radiometer (CAR) aboard NASA's P-3B aircraft (Figure 2), acquired surface bidirectional reflectance-distribution function (BRDF) data over seven well characterized terrestrial ecology study sites along the U.S. east coast. Two other instruments developed at GSFC (DBSAR: Digital Beam-forming Synthetic Aperture Radar, and Slope Imaging Multi-polarization Photon-counting Lidar, SIMPL) were part of ECO3D, but will not be discussed in this pilot study.

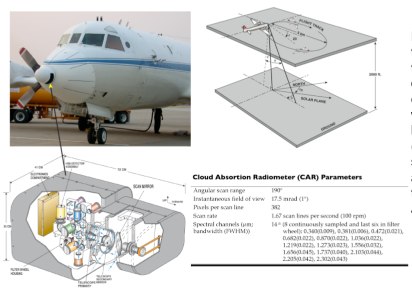


Figure 2. (a.) NASA P-3B with the CAR instrument mounted in the nose cone. (b.) Schematic of CAR. (c.) Illustration of a clockwise circular flight track that was used for measuring surface-level bidirectional reflectances. (d.) The CAR has 14 narrow spectral bands between 0.34 and 2.30 µm. During ECO3D, the CAR flew 12 missions in August-September, 2011.

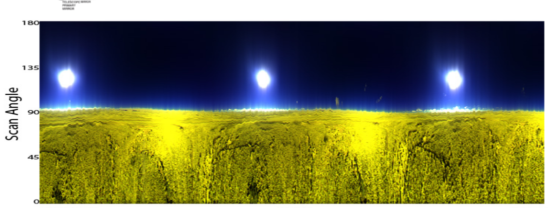


Figure 3. CAR Quicklook Image over Harvard Forest on September 19, 2001 during ECO3D. CAR BRDF measurements cover an area on the order of kilometers in diameter. A complete circular orbit by the aircraft is defined by two solar disks in the above quicklook image.

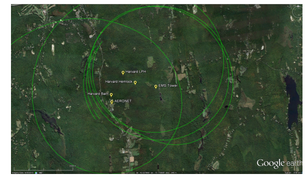
One of the strengths of the CAR is its unique ability to measure almost simultaneously, both downwelling and upwelling radiance. Its unique viewing geometry of 190° makes it most suitable for measuring BRDF even under low sun conditions with a better accuracy than any other known airborne sensor. Data are acquired at a high angular (1°) and spatial resolution (better than 10 m at nadir, assuming 600 m altitude) coupled with a high signal-to-noise ratio.

Multiangular observations are governed by the view-illumination geometry, and thus, contain information on the physical structure of the upper (tree and/or shrub) canopy and (soil and/or low vegetation) background. This investigation exploits these data to demonstrate tree height retrieval using the spectral invariant technique (Knyazikhin et al.,1998; Huang et al., 2007; Wang et al., 2011).

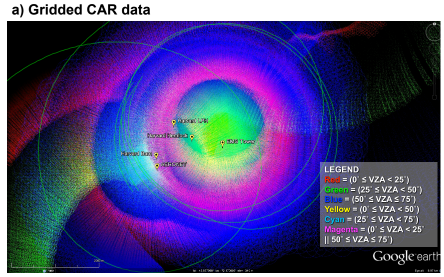
Geolocation and Gridding of CAR data

The geolocation accuracy of Eco/3D Flt. 2036 is ~2.0-3.5 meters as derived from the high resolution World-View-2 scene collected over Harvard on 02 Sept, 2011 and compared to the UTM coordinates for CAR, assuming a 'flat-earth.' Note that the total number of observations shown in (a) below is 358,914. Observations with pixel sizes >250m are excluded. b) flight track over Harvard forest. c) Spatial distribution of the semi-empirical reciprocal RossThick-LiSparse model parameter for the surface reflectance (Fiso) using CAR bands (5, 4, 3) or (0.87, 0.68, 0.47µm).

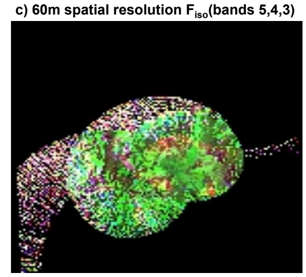
b) P-3/CAR flight track



a) Gridded CAR data

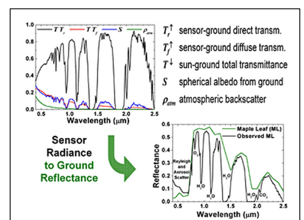


c) 60m spatial resolution F_{iso}(bands 5,4,3)

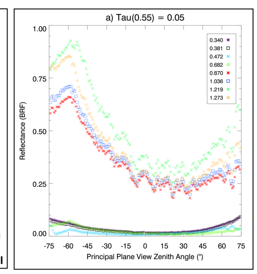


Atmospheric Correction

In the past, various radiative transfer (RT) schemes have been used for the atmospheric correction of CAR data (e.g., Gatebe et al., 2003, 2005; Román et al., 2011; Lyapustin et al., 2010). In this study, we used the MODTRAN®5 RT code (Berk et al., 2004).



MODTRAN®5 atmospheric correction data (top) and a mapping of radiance to reflectance obtained from the data (bottom).
from: http://modtran5.com/features/index.html



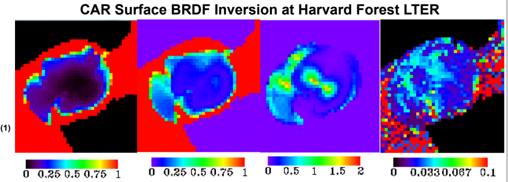
Retrieval of Surface BRDF and Spectral Invariant Parameters

BRDF parameters and WOD (weight of determination) from the atmospheric-corrected reflectance data over Harvard Forest. Nb. WSA – white sky albedo, NBAR45: Nadir BRDF-Adjusted Reflectance; QA: quality assurance, Fiso – Isotropic parameter. Lower WOD values indicate better retrieval. Spectral invariant parameters retrievals are based on:

$$BRF_{\lambda}(\Omega) = \rho(\Omega)\omega_{\lambda} i_0 + \rho(\Omega)\omega_{\lambda}^2 p\, i_0 + \ldots + \rho(\Omega)\omega_{\lambda}^m p^{m-1} i_0 + \ldots = \frac{\omega_{\lambda}}{1-\omega_{\lambda} p} R_1(\Omega) \quad (1)$$

$$\frac{BRF_{\lambda}(\Omega)}{\omega_{\lambda}} = p\,BRF_{\lambda}(\Omega) + R_1(\Omega) \quad (2)$$

CAR Surface BRDF Inversion at Harvard Forest LTER

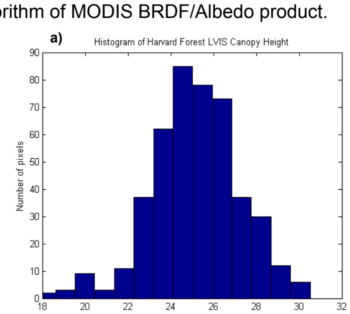


WOD WSA | WOD NBAR45 | QA | F_{iso}(Red)

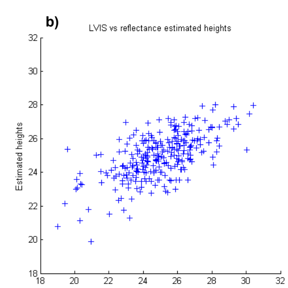
Canopy Height Retrieval/Harvard Forest

This is deduced from the spectral invariant theory by Knyazikhin et al. [1998], which states that the spectral dependence of canopy reflectance and transmittance can be described by spectrally invariant parameters such as escape probability and recollision probability. In this research, the escape probability are calculated from the Eq (2) where the BRFs are the CAR BRDF along the principal plane with the same solar zenith angle. And BRFs can also be generated from CAR data with the same algorithm of MODIS BRDF/Albedo product.

a)



b)



a) Histogram of LVIS canopy height over Harvard Forest (https://lvis.gsfc.nasa.gov; Blair et al., 1999). b) Correlation coefficient: Multi angles surface reflectance 0.65; escape probability: 0.76; maple leaf reflectance and broadleaf pixels. Spatial resolution: 240m

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Wang, et al. 2011: Remote Sensing of Environment, 115, 1595-1601.

For more info: http://car.gsfc.nasa.gov/data/: ECO-3D